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A MULTIBAND SHORTWAVE ANTENNA FOR SWLs

Transmission-line traps of novel construction allow this antenna to resonate on the 49-, 31-, 25-, 19-, 16-, 13-, and 11-meter shortwave bands

BY ROBERT H. JOHNS

TODAY'S shortwave receivers are so sensitive that simple random-length wire antennas are all that's needed for casual listening. However, serious DXing—picking up signals from distant, low-power stations, for example—calls for a resonant antenna. The classic method of resonating an antenna is cutting it to the appropriate length, but that implies the use of several antennas for multiband reception. A much more convenient approach is possible. The Multiband Shortwave Antenna employs *traps* that automatically adjust its effective length to resonate with the received signal. It can be constructed from

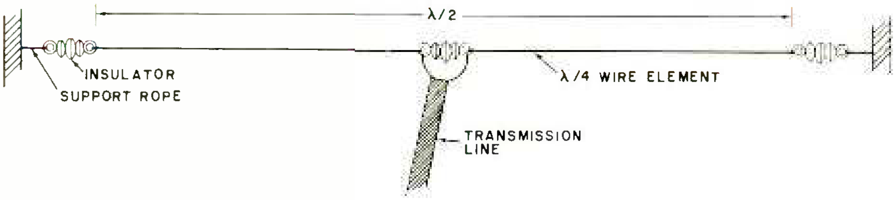

Fig. 1. The basic half-wave dipole antenna.

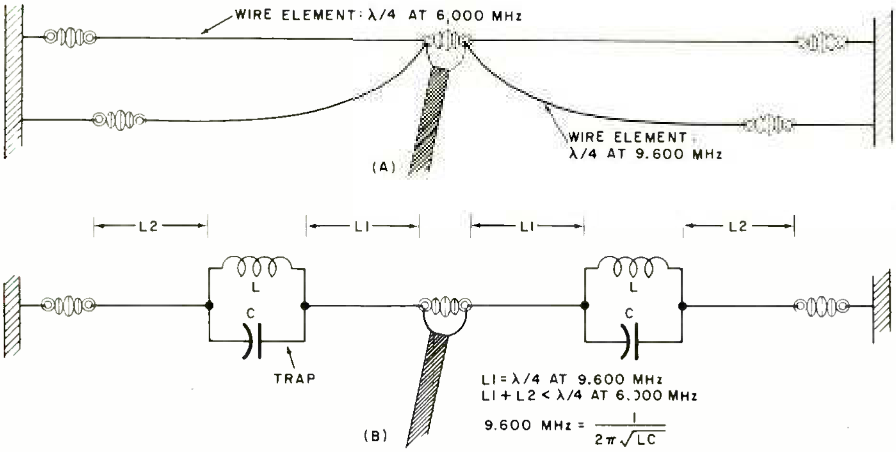

Fig. 2. (A) Two or more half-wave dipoles can be connected in parallel to a single transmission line for dual- or multi-band coverage. (B) A dipole antenna with a single pair of traps can resonate on two different bands.

PARTS LIST

Hard-drawn copper antenna wire; 7/8-inch diameter plastic tubing or PVC pipe; ceramic end insulators; 300-ohm twinlead, ceramic center insulator and silicone weatherproofing compound or 50- or 75-ohm coaxial cable and combination center insulator/4:1 balun transformer (see text); nylon rope; suitable supporting structures; two 35-foot spools of Radio Shack two-conductor Rainbow Wire (Catalog No. 278-755) or equivalent; solder, suitable hardware, in-line lightning arrestor, etc.

***Note:** A trap antenna for the 11-, 13-, 16-, 19-, 25-, 31-, and 49-meter bands with 50 feet of 72-ohm twinlead transmission line is available for $29.50 from Scientific Instruments, 3379 Papermill Rd., Huntingdon Valley, PA 19006.*

readily available, inexpensive materials and can perform well on the major international broadcast bands.

About the Antenna. The basic antenna from which the multiband trap design is derived is the half-wave dipole. As shown in Fig. 1, the dipole consists of two elements and has an effective length of one-half wavelength at the frequency of resonance. Effective length is not necessarily equal to the actual physical length. An antenna can be made to exhibit an effective length greater than its physical length by the introduction of inductive reactance. Similarly, an antenna's effective length can be made less than its physical length by the introduction of capacitive reactance.

An antenna that resonates at 6.000 MHz in the 49-meter international shortwave broadcast band is 77 feet long, and one that resonates at 9.600 MHz in the 31-meter band is 48 feet long. The classic way to construct an antenna that resonates at these two frequencies involves connecting two dipoles, each cut for one of the frequencies of interest, to a common transmission line that feeds signals to the receiver (see Fig. 2A). Each dipole is active at and near its resonant frequency. Its effect on the performance of the other, whose resonant frequency is far removed, is minimal.

The trap approach to the problem of providing a resonant antenna at these two different frequencies is shown in Fig. 2B. It comprises a transmission line, four lengths of wire, and two traps or parallel LC networks that resonate at 9.600 MHz. At resonance, the impedance of the traps is very high and purely resistive. Above resonance, the trap impedance is lower and capacitive. Similarly, below the resonant frequency, the trap impedance is lower and inductive.

The inner wire sections of the antenna comprise a half-wavelength at 9.600 MHz. When the antenna is excited by r-f energy at that frequency, the high resistance of the traps (practically open circuits) decouples the outer wire sections from the inner sections. The antenna thus acts as a half-wave dipole cut for resonance at 9.600 MHz.

At the second, lower frequency of interest (6.000 MHz), the traps are not resonant. Rather, they behave like inductive reactances. When the antenna is excited by a 6.000-MHz r-f signal, the outer wire sections of the antenna are effectively connected to the inner sections through these inductive reactances. The total physical length of the antenna is shorter than would normally be required for resonance at 6.000 MHz. However, the antenna's effective or electrical length is a half-wavelength. The reason for this is that the inductive reactance of the traps supplies the needed electrical length. The traps function as loading coils at this lower frequency and the antenna resonates. This physical shortening of the antenna can be of particular advantage where space is limited.

There is no reason why more than one set of traps cannot be installed in an antenna for operation on more than two bands. That's exactly what's done in the Multiband Shortwave Antenna shown in Fig. 3. Each leg of the antenna contains six traps, allowing the antenna to exhibit resonance on the 49-, 31-, 25-, 19-, 16-, 13- and 11-meter bands. Although it resonates only on those bands, it will offer good performance in other

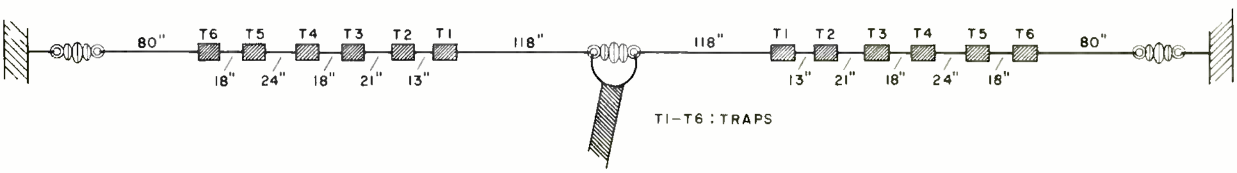

Fig. 3. The Multiband Shortwave Antenna employs six pairs of traps.

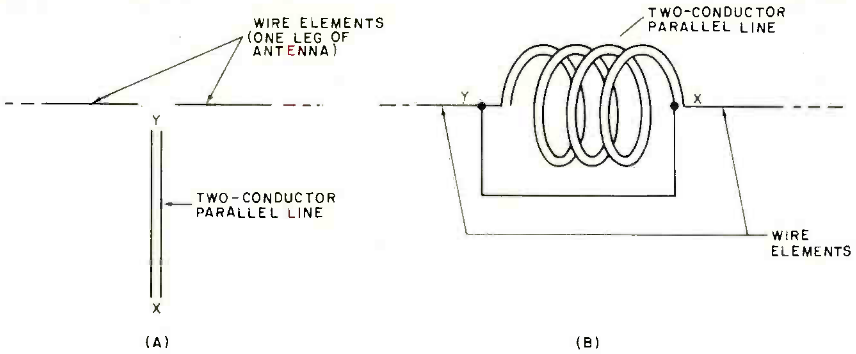

Fig. 4. How a two-conductor parallel transmission line (A) can be made into a trap by coiling it and using its distributed capacitance (B).

portions of the hf spectrum. The traps also shorten the antenna considerably compared to a full-size dipole cut for the 49-meter band.

Construction. The traps used in the Multiband Shortwave Antenna are assembled from inexpensive, lightweight, and readily available materials. Two-conductor parallel transmission line—actually, Radio Shack two-conductor Rainbow Wire, Catalog No. 278-755—is employed. It has an interconductor capacitance of approximately 15 pF per foot. Refer to Figs. 4, 5, and 6 for trap details.

To simplify construction, one wire of the pair is employed as the trap's inductor, and the distributed capacitance between it and the other conductor forms the trap's capacitor. A suitable length of two-conductor line with ends *X* and *Y*, as shown in Fig. 4A, is selected. The line is wound into a helix and its conductors connected to two of the wire elements of one leg of the antenna as in Fig. 4B.

One conductor has its *X* and *Y* ends connected to each of the two wire elements. The *Y* end of the other conductor is left floating; the *X* end is connected back to the *Y* end of the other. The result is an LC parallel network whose inductance and capacitance are determined by the pitch of the line's helix, the number of turns comprising the helix, and the length of the line. For mechanical support, the line is wound on an electrically inert, plastic cylindrical form.

The prototype antenna was made using lengths of ⅞-inch outer-diameter polypropylene tubing. This tough, light material was salvaged from a hula hoop that had steel balls inside the tubing. Some other electrically inert material such as PVC pipe can be used as the trap forms, but the coil-winding data in the box, "Details of Trap Construction," is valid only for cylindrical forms with outside diameters of ⅞ inch.

Begin construction by cutting 12 suitable lengths of tubing (two of each length listed in the box for traps *T1* through *T6*). Drill four holes approximately ½ inch from the ends of each length of tubing, using Fig. 5 as a guide. Then take one of the 2¾-inch forms and slip one end of two suitable lengths of antenna wire through two of the holes at each end of the form. The form will support trap *T6* of the left leg of the antenna (see Fig. 3) and the two wire elements will be the "80-inch" and the outer "18-inch" components of that leg.

Note that the wire lengths given in Fig. 3 are those between end insulators and traps, between traps, and between traps and the center insulator. Several extra inches of wire will be needed at each end to form loops and wraps, so make allowances before cutting. The wire can be insulated or bare, stranded or solid, but it should be hard-drawn copper. Soft-drawn copper has a tendency to stretch under load. An antenna made from it will deform and sag, thus detuning itself.

The other end of the "80-inch" wire should be fed through one end of a ceramic antenna end insulator (*not* an "egg" type guy-wire insulator) and wrapped back upon itself for mechanical support. For additional strength, the end of the antenna wire should be soldered where it is wrapped. Feed the other end of the "80-inch" wire through two of the holes at the left end of the 2¾-inch form and wrap it back upon itself, adjusting its length so that the distance between the end of the ceramic insulator and the left end of the trap form is exactly 80 inches. This wrap should not be soldered yet—it will be soldered later, when the assembly of trap *T6* is completed.

Next, slip one end of the "18-inch" wire through two of the holes at the right end of the trap form and wrap it back upon itself. Then separate the conductors at one end of a length of Radio Shack Rainbow Wire for several inches and cut the white wire short by five inches. Remove ¾ inch of insulation from each of the wires. Slip the shortened end of the white wire through one of the two remaining holes on the right side of the trap form and wrap it around the antenna wire. Then slip the end of the black wire through the remaining hole and pass it through the interior of the trap form so that it exits at the left

DETAILS OF TRAP CONSTRUCTION

Trap Number	Band (meters)	Resonant Frequency (MHz)	Number of Turns	Length of Trap Form (inches)
T6	31	9.6	18	2.75
T5	25	11.7	15	2.50
T4	19	15.3	11.5	2.00
T3	16	17.7	9.5	1.75
T2	13	21.8	8.5	1.50
T1	11	25.8	7.5	1.50

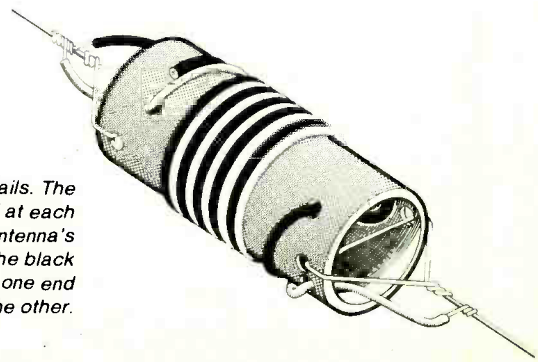

Fig. 5. Trap wiring details. The white wire is connected at each end to one of the antenna's wire elements. The black wire is left floating at one end and cross-connected at the other.

Fig. 6. Two of the antenna's wire elements have been connected to the plastic form and the Rainbow Wire attached.

side. Wrap the exposed conductor of the black wire around the end of the antenna wire.

Next, closely wind 18 turns of the Rainbow Wire around the form from right to left. Cut the wire after the 18th turn, leaving several inches for connection. The black wire should be separated from the white and cut at the completion of the 18th turn. Strip the insulation from the end of the white wire and wrap it over the antenna wire and the black wire that runs from the other end of the trap form. Solder the wires at ends of the form, but do not apply too much heat or the plastic tubing will melt. Trap *T6* of the left leg is now complete, and should resemble the trap that is shown in Fig. 7.

Following the same procedure, assemble the remaining traps and wire elements of the left leg, working in toward the center point of the antenna. The lengths of the trap forms and the number of turns comprising each of the remaining traps are specified in the box. Inter-trap distances that are related to the lengths of the remaining wire elements of the left leg appear in Fig. 3.

When assembly of the left leg of the antenna has been completed, the right leg can be constructed. Follow the same procedure. As before, assembly should begin at the outer extremity and finish with the 118-inch inner section.

If you have access to a grid-dip meter, you can check the resonant frequencies of the traps. They should be close to those listed in the box. If a trap's frequency of resonance is incorrect, it can be adjusted by spacing the turns out somewhat (to raise the frequency) or by squeezing them closer together (to lower the frequency). Larger changes should not be necessary, but can be accomplished by adding or removing turns. When the desired resonant frequencies have been obtained, the trap windings can be secured in place with coil dope or epoxy cement.

When both legs of the antenna have been assembled, they should be connected to a transmission line and a center insulator. To prevent deterioration of the transmission line, a weatherproof center insulator should be used. Alternatively, a ceramic end insulator can be employed, and silicone weatherproofing compound applied after the connections between the inner wire elements of the antenna and the transmission-line conductors have been soldered. Similarly, weatherproofing of the traps is recommended to prevent moisture buildup from detuning the traps. This can be accomplished by enclosing each trap in a cylindrical Plexiglas or PVC form.

Fig. 7. A completed trap ready to be soldered. Note that the Rainbow Wire has been closely wound around the form.

Two factors influence the choice of transmission line: the impedance of the antenna and its electrically balanced nature. A dipole fed at its center and mounted in free space has an impedance of 72 ohms, but a dipole mounted close to the ground in terms of wavelength will have a different impedance. The impedance plot of the prototype Multiband Shortwave Antenna, which was mounted approximately 20 feet above ground, appears in Fig. 8. It is readily apparent that the impedance of the antenna as measured by the author varies considerably across the hf region of the radio spectrum. At resonance in the 49- and 11-meter bands, the feedpoint impedance is approximately 70 ohms, but it is higher in the other shortwave broadcast bands for which it is designed, even at resonance.

The prototype was fed with 300-ohm twinlead for three reasons. First, its impedance is a good compromise, considering the wide variation in the feedpoint impedance of the antenna. Second, twinlead is a balanced line, making it appropriate for use with the dipole, an electrically balanced antenna, and for use with shortwave receivers that have balanced-input antenna terminals. Finally, twinlead is relatively inexpensive and easy to work with.

If you decide to use 300-ohm twinlead, select a high-quality line. It should be foam-filled to keep signal losses low and to minimize the deleterious effects of dirt and moisture that build up on the line's outer jacket. The best balanced line to use is shielded twinlead. It is the most expensive and is somewhat more difficult to work with than thinner, flatter varieties. However, shielded twinlead has a considerably greater useful lifetime (ordinary twinlead deteriorates rather rapidly outdoors) and its impedance is not disturbed by nearby metallic objects.

Coaxial cable can also be used as the lead-in for the Multiband Shortwave Antenna. A 75-ohm coaxial line such as RG-59/U weathers well and has relatively low losses. The fact that it is shielded means that it can be passed near metallic objects or even buried underground without adverse electrical effects. If 75-ohm coax is to be used, it should be teamed up with a 75-ohm-to-300-ohm balun transformer. The balun will step up the impedance of the line at the antenna's feedpoint and make for a better match between the unbalanced transmission line and the balanced dipole antenna. As a bonus, most baluns

designed for amateur-radio use double as weatherproof center insulators. If you decide to employ coaxial line and a balun, make sure that the balun is of the 4:1, as opposed to the 1:1, variety. Many contemporary shortwave communications receivers have unbalanced, low-impedance antenna inputs, so in most cases a second balun transformer won't be needed at the receiver end of the transmission line.

Installing the Antenna. There are two basic ways that the Multiband Shortwave Antenna can be set up at the receiving site—either as a flattop dipole or as an inverted vee (see Fig. 9). The flattop dipole has a higher feedpoint impedance than an inverted vee and is somewhat directional—it responds best to signals striking it at right angles. It requires two high supports (Fig. 9A), one at each end of the antenna. In most cases, the dipole does not require a center support.

The inverted vee (Fig. 9B) is more omnidirectional and has the advantage of requiring only one high support at the center. This also lessens the stress on the antenna structure. Although the feedpoint impedance of the inverted vee is somewhat lower than that of a flattop dipole, it is still a good match for 300-ohm twinlead or a coax/balun combination, but slightly better results will be obtained with 50-ohm coax than with 75-ohm line.

Nylon rope should be used between the insulators and the antenna supporting structures. In the case of a flattop dipole whose ends are supported by trees, the ropes should pass through halyards attached to the trees and their ends secured to weights. This will allow the antenna to remain stationary even when the supporting structures sway in the wind. If the metallic mast is used to support the center of an inverted vee, tension should be placed on the antenna wires and the feedline to keep them at least several inches away from the mast. In any event, try to keep the feedline at right angles to the antenna for as long a run as possible. The use of an in-line lightning arrestor is also highly recommended for safety's sake.

If only a limited space is available for installation, the ends of the antenna can be bent at right angles. The straight, central portion of the antenna should be as long as possible. The antenna can be installed in an attic, but best results will be obtained if the antenna is mounted straight, in the clear, outdoors, and as high as possible.

For really tight quarters, an excellent performer on the 11-, 13-, 16- and 19-meter bands can be built by eliminating traps *T4*, *T5*, and *T6* and the three outer wire sections of each leg of the antenna. This shortened version has an overall length of approximately 28 feet and will also do a good job, though not as good as a full-size antenna, on the lower-frequency bands. ◇

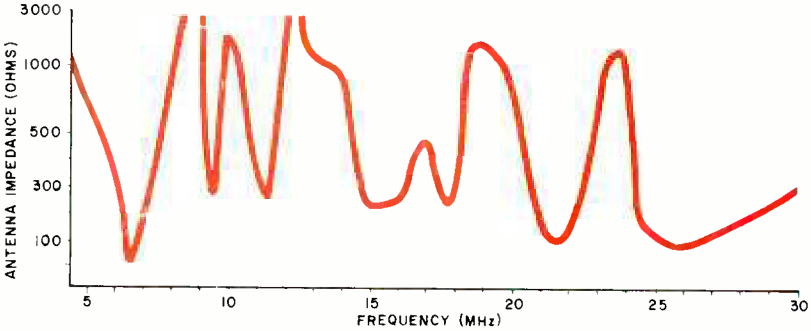

Fig. 8. A impedance plot of the author's prototype installed at a height of 20 feet.

Note—*Readers are encouraged to build the traps described in this article for their own use, but are cautioned that a patent application has been filed on this and other types of transmission-line traps.*

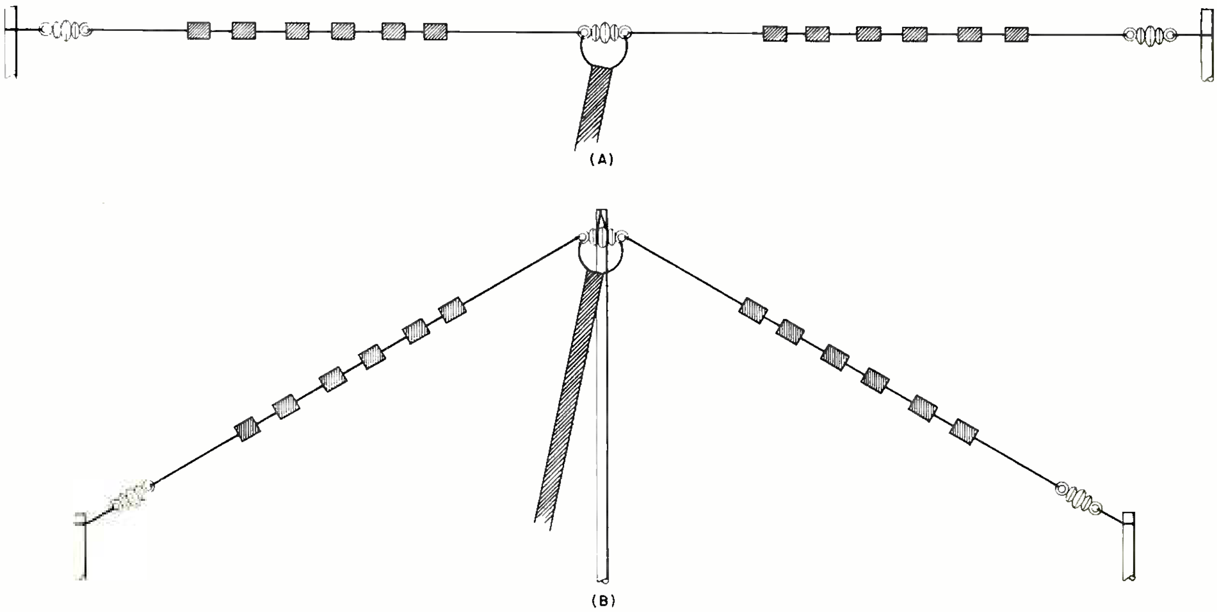

Fig. 9. Two ways to install the Multiband Shortwave Antenna—as a flattop dipole (A) and as an inverted vee (B).